

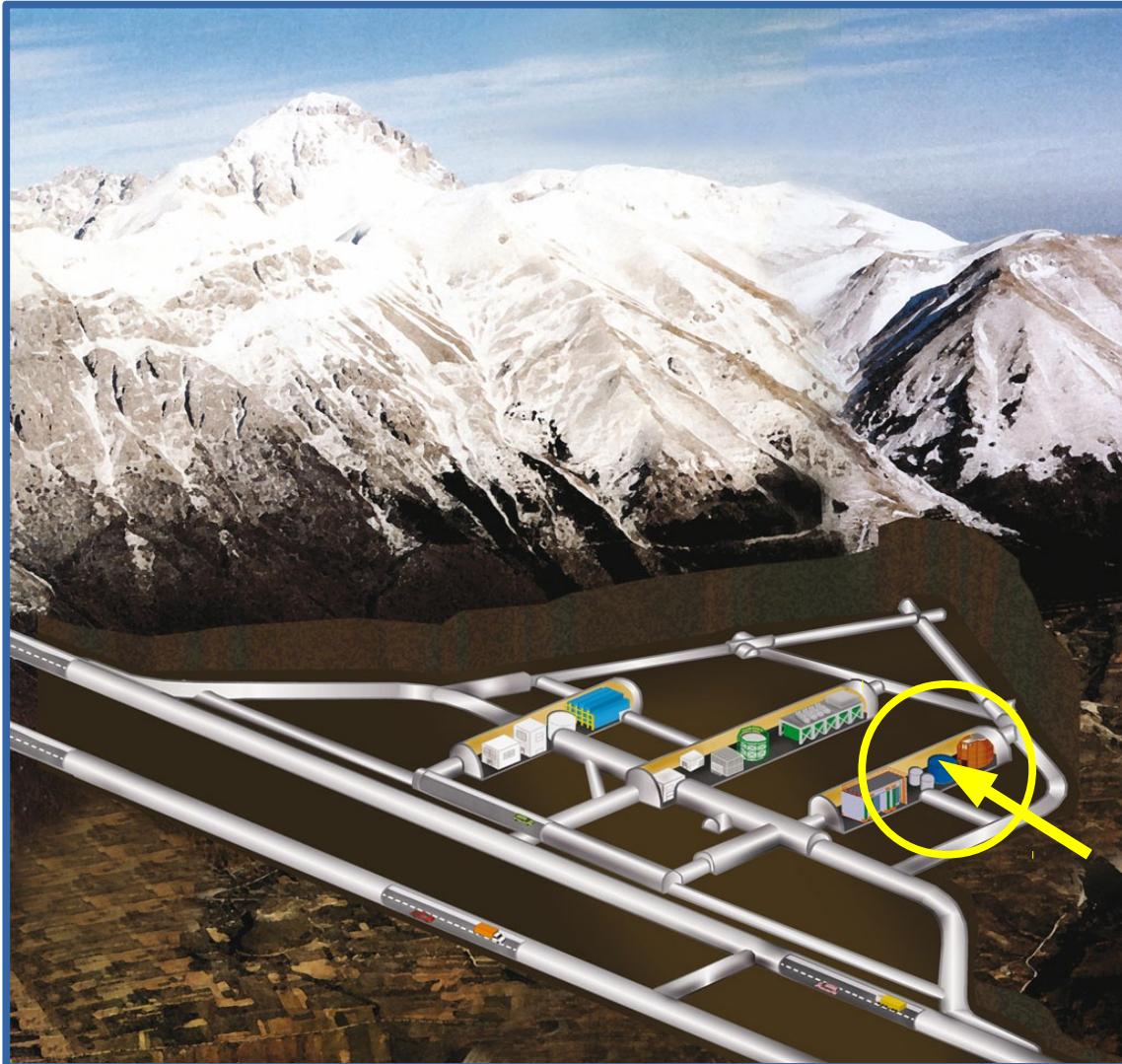
17<sup>th</sup> Lomonosov Conference – ICAS  
Moscow, Aug 19-26, 2015.

# The DarkSide-50 Experiment: a Liquid Argon Target for Dark Matter Particles



Nicola Rossi  
on behalf of the DarkSide-50 Collaboration  
LNGS (INFN), Italy.

# The DarkSide-50 Experiment



Laboratori Nazionali del Gran Sasso – INFN (Italy)  
(3800 w.e. depth)

## DarkSide-50

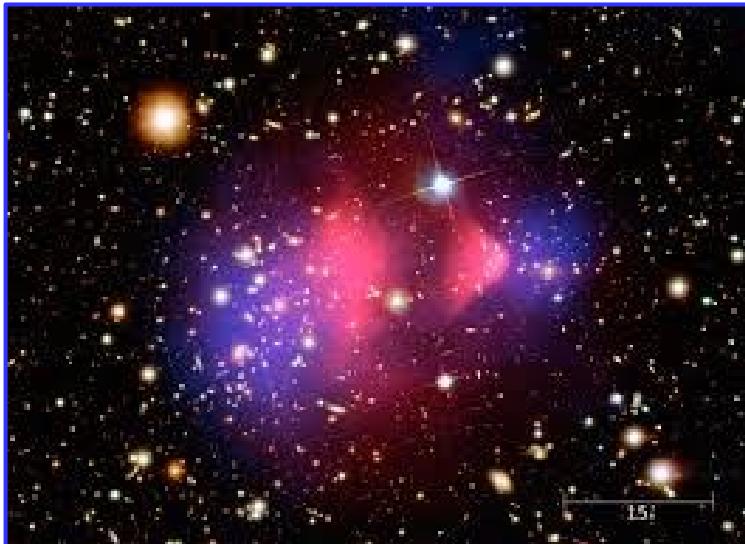
- in Hall C of the Laboratori Nazionali del Gran Sasso (LNGS)
- Dark Matter Particle search with double phase Ar **Time Projection Chamber (LAr-TPC)**
- Low background:  
**Underground (depleted) Argon (UAr)** with reduced content of  $^{39}\text{Ar}$  present in the **Atmospheric Ar (AAr)**

# The DarkSide-50 Collaboration

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- (4) [Kavli Institute, Enrico Fermi Institute and Dept. of Physics, University of Chicago](#)
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- (13) [Smoluchowski Institute of Physics, Jagiellonian University, Krakow](#)
- (14) [Institute for Nuclear Research, National Academy of Sciences of Ukraine](#)
- (15) [National Research Centre Kurchatov Institute](#)
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- (18) [Physics Department, Università degli Studi and INFN, Milano](#)
- (19) [Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University](#)
- (20) [Physics Department, Università degli Studi Federico II](#)
- (21) [St. Petersburg Nuclear Physics Institute, Gatchina](#)
- (22) [Chemistry, Biology and Biotechnology Department, Università degli Studi and INFN, Perugia](#)
- (23) [Department of Physics, Princeton University, Princeton](#)
- (24) [Physics Department, Università degli Studi Roma Tre](#)
- (25) [SLAC National Accelerator Laboratory](#)
- (26) [IPHC, Université de Strasbourg](#)
- (27) [Physics Department, Temple University](#)
- (28) [Physics Department, University of California](#)
- (29) [Physics and Astronomy Department, University of California](#)
- (30) [Amherst Center for Fundamental Interactions and Physics Department,](#)
- (31) [Physics Department, Virginia Tech](#)



# The Dark Matter Search



Stable, neutral, low interactive particles are expected in many extensions of the Standard Model

## ***“Direct” interaction search:***

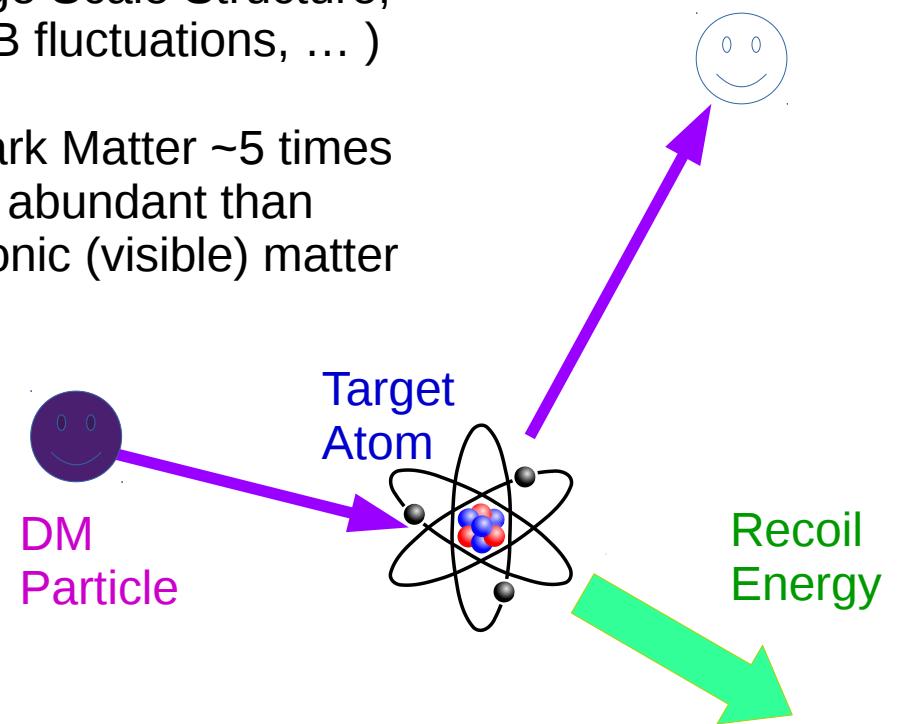
- very low background (underground lab)
- high background rejection power
- energy threshold < 100 keV

If we believe that the fundamental physical laws (we deduced from our perspective) work for the the whole Universe, Dark Matter must should exist.

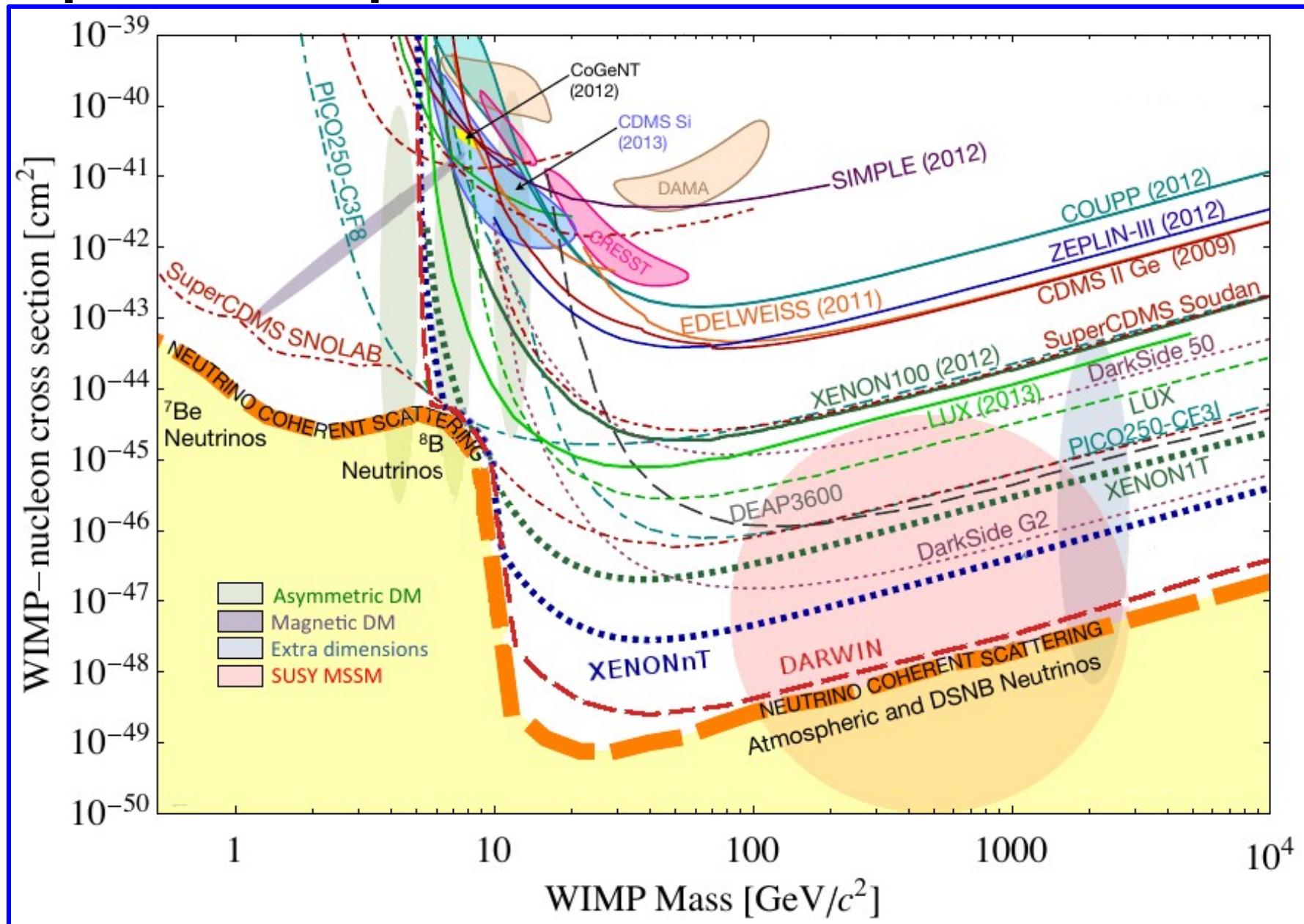
## ***“Indirect” astrophysical observations:***

- galaxy and cluster dynamics,
- Large Scale Structure,
- CMB fluctuations, ... )

→ Dark Matter ~5 times more abundant than Baryonic (visible) matter



# Spin-independent current scenario



# Why LAr TPC?

## A<sup>Ar</sup>:

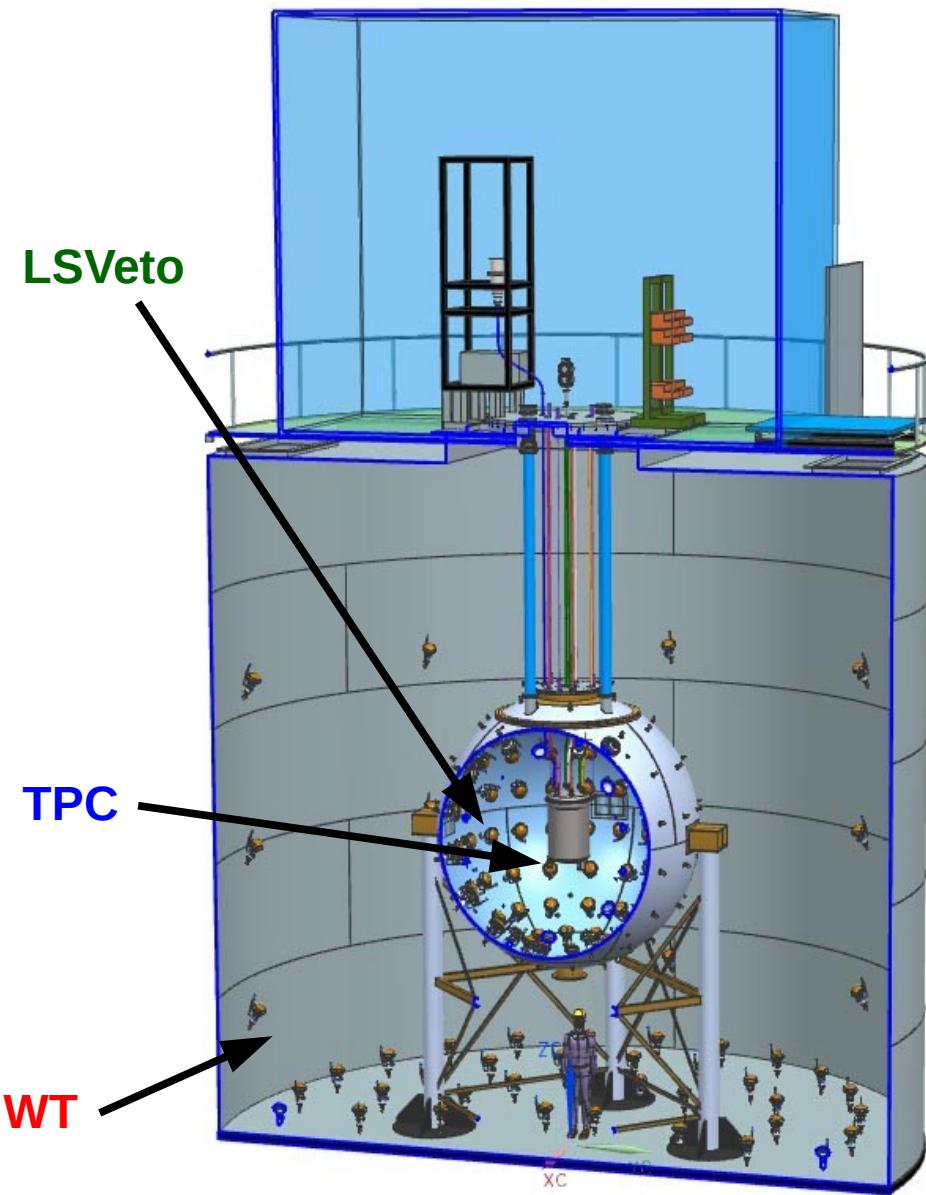
- **Both scintillation and ionization:** S2/S1 electron recoil (ER) and nuclear recoil (NR) discrimination, position reconstruction (x, y, z), fiducialization, energy correction, multi-site event rejection
- **Abundant** (cheap, scalability to multi ton)
- Sufficient **self shielding** ( $A = 40$ )
- **Excellent e.m. background discrimination** (slow (6 ns) and fast component (1600 ns), even in single phase)
- **Established technique**
- **High Energy recoil** not strongly suppressed by form factor (Also with high threshold)
- **High Light Yield (LY):** 40 PE/keV
- **Promising competitor** with the Xe for the multi-ton scale



## U<sup>Ar</sup>

- $^{39}\text{Ar}$  background reduced by a factor < 1/300
- Cheap if the production starts to be massive

# The DarkSide-50 Concept



Three nested detectors:

## TPC:

- 38 3" PMT (R11065) low radioactivity + Cold amplifiers
- Stainless steel cryostat, 150 Lt
- HHV: drift and extraction fields

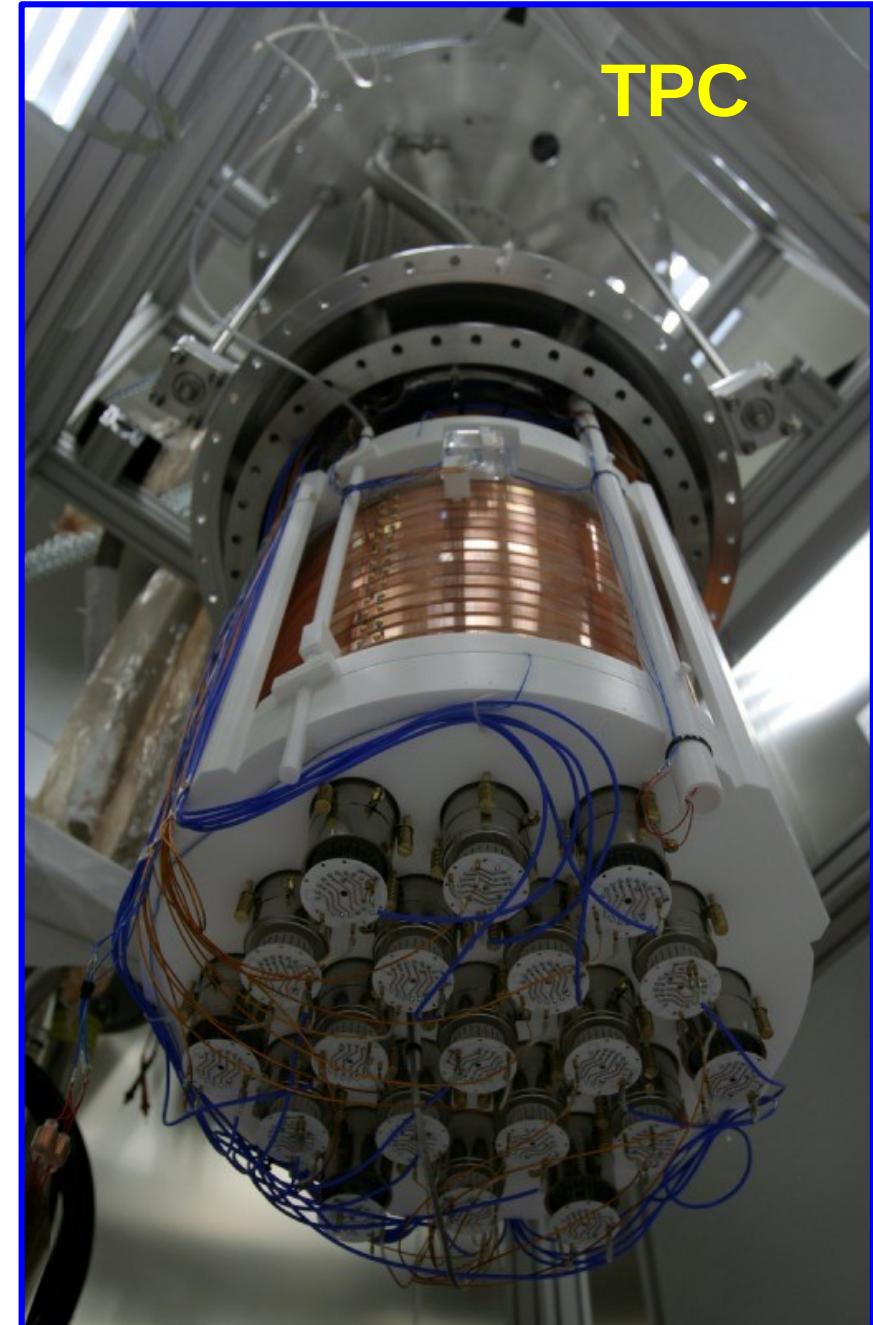
## LSVeto:

- Stainless sphere
- 1.5 m active shielding,
- 110 8" PMT
- Scintillator:  
30 ton TMB (5%) + PC
- 99.5 % efficiency

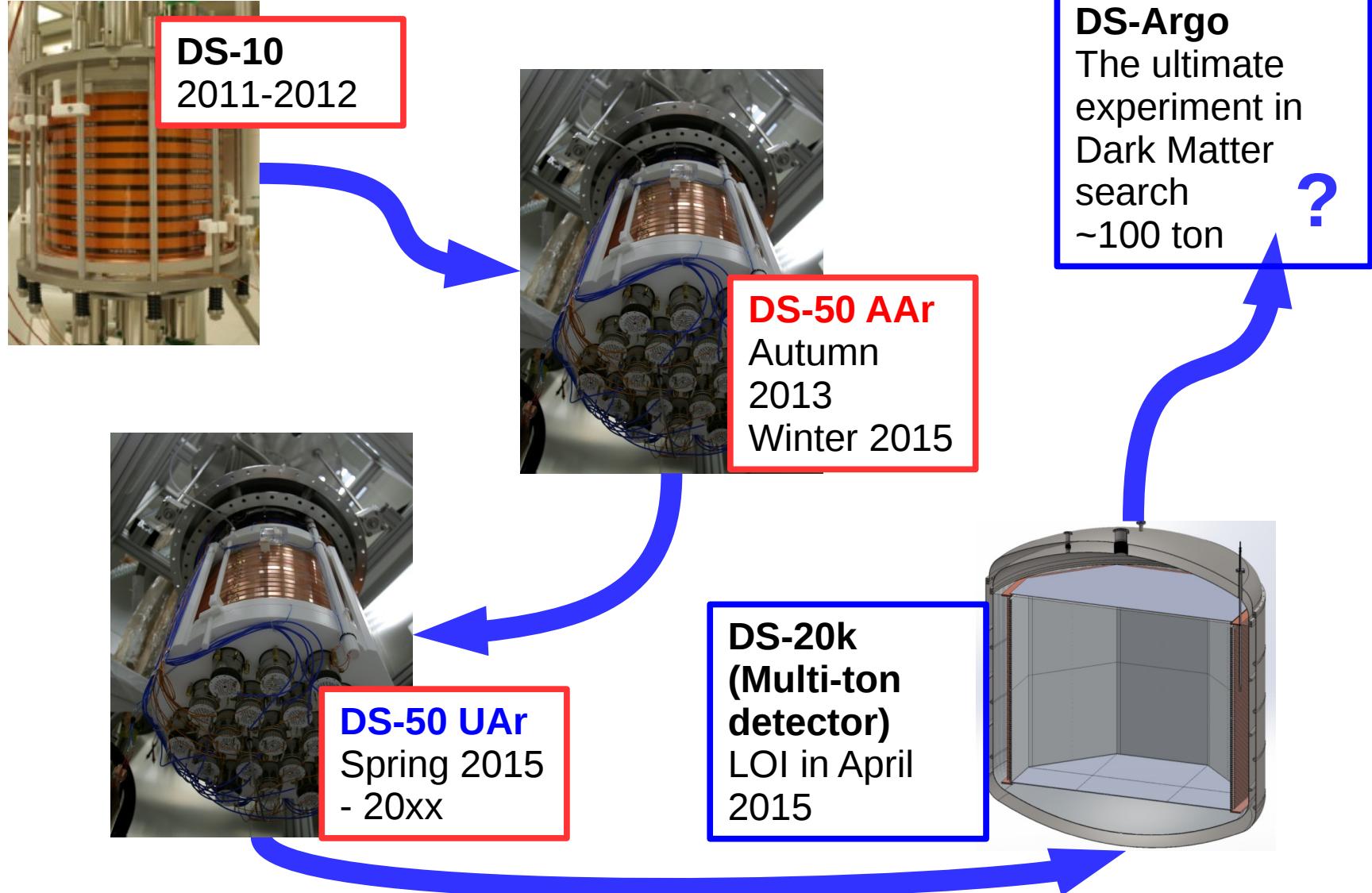
## Water Tank:

- 1000t high purity water
- 80 8" PMT

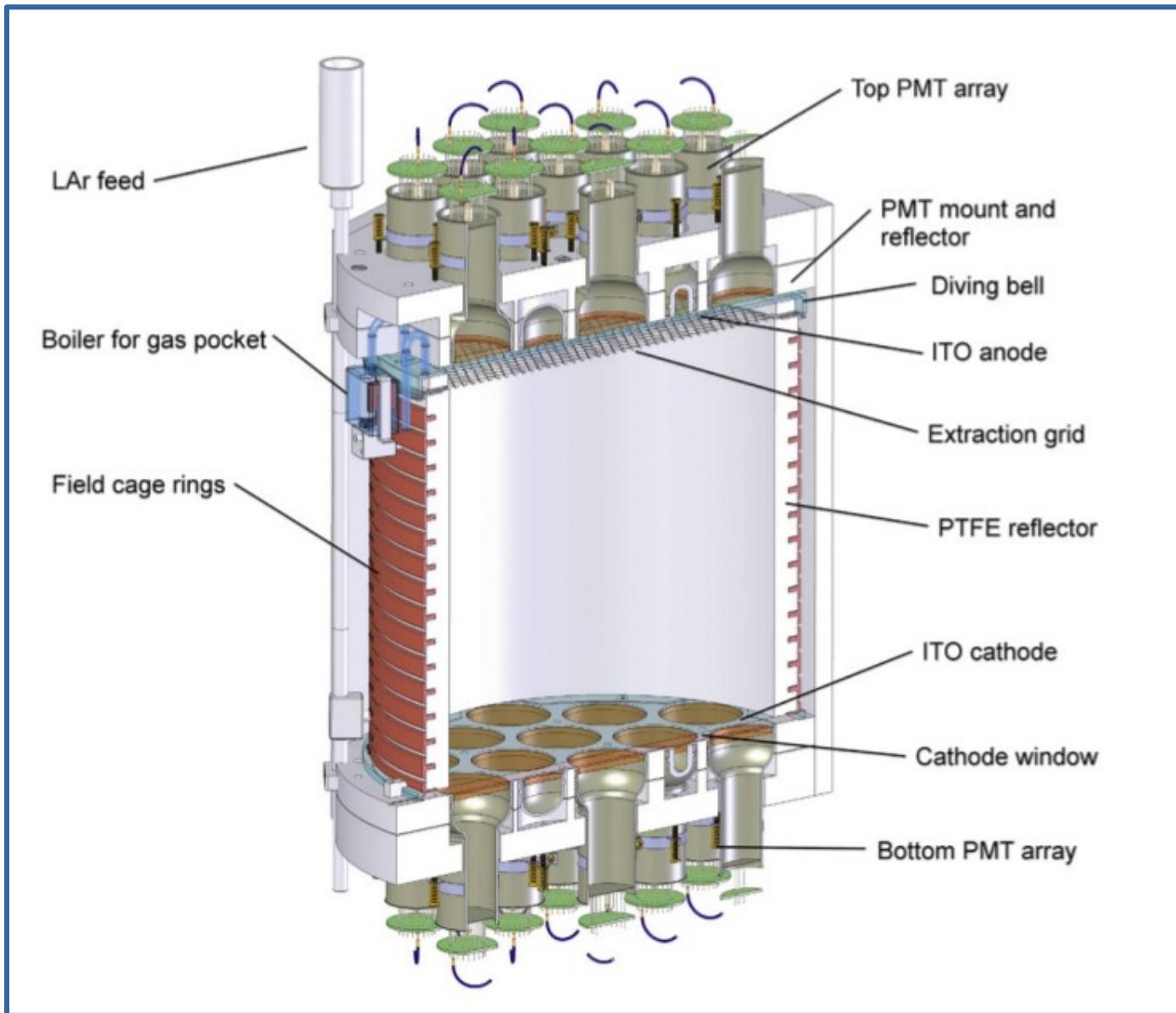
# Detector pics before the filling



# The DS-50 timeline



# The 2-phase TPC



## TPC scheme

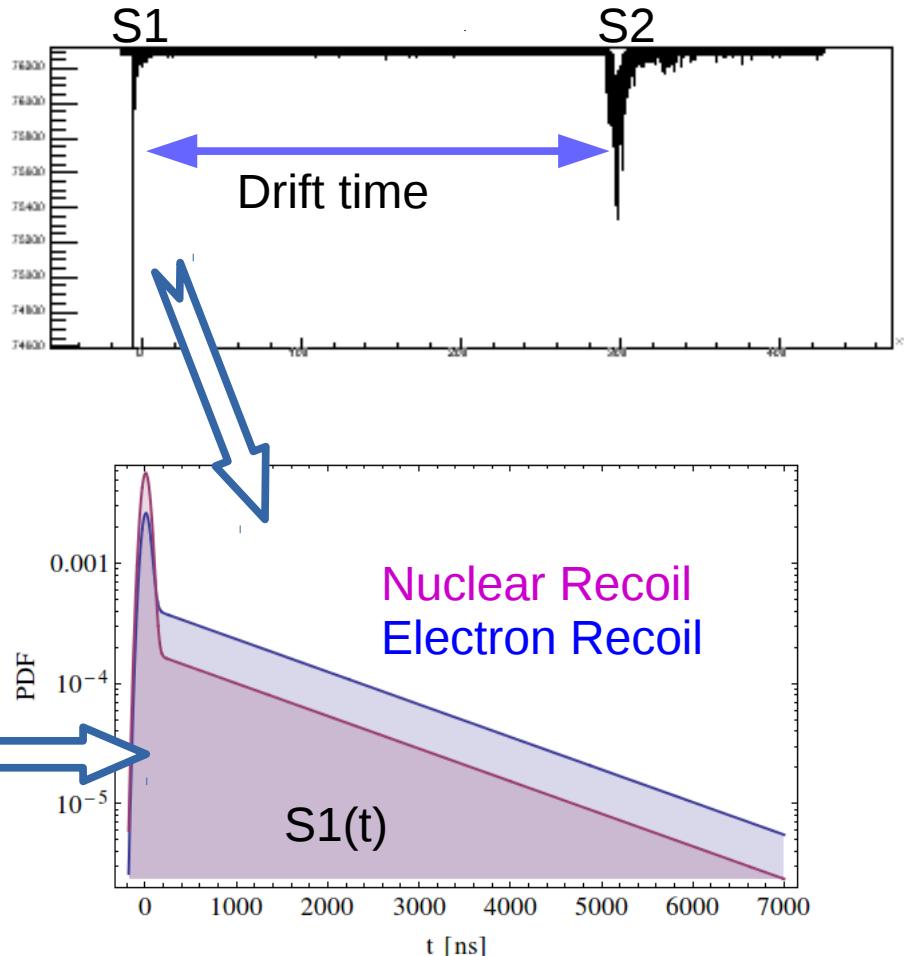
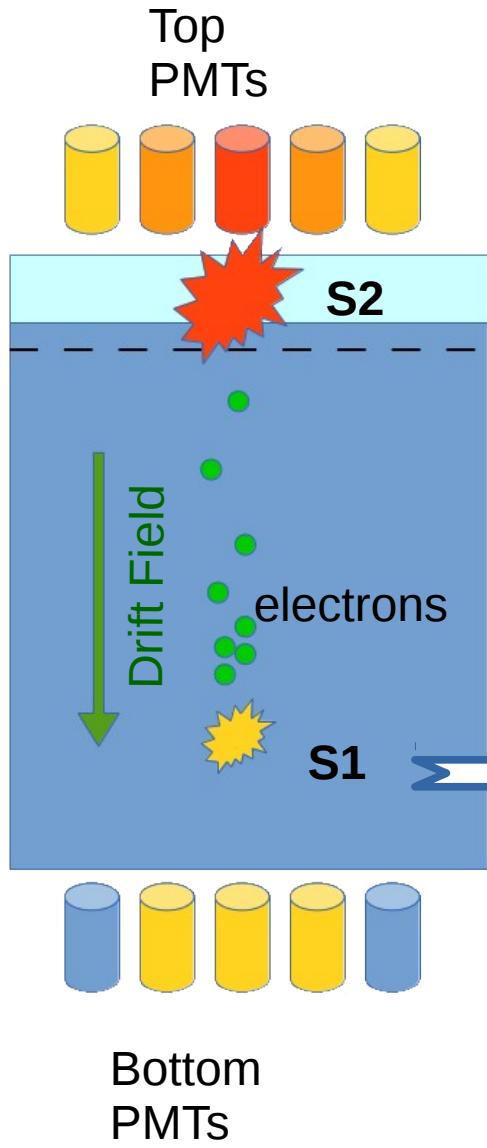
TBP wavelength shifter  
on the walls

19 PMT on the top  
and 19 on the bottom  
with cold amplifiers

**Drift Field:**  
0.2 kV/cm

**Extraction Field:**  
2.8 kV/cm

# The DarkSide-50 Signal



Z position through S1-S2 drift time

X, Y position through S2 light on top PMTs

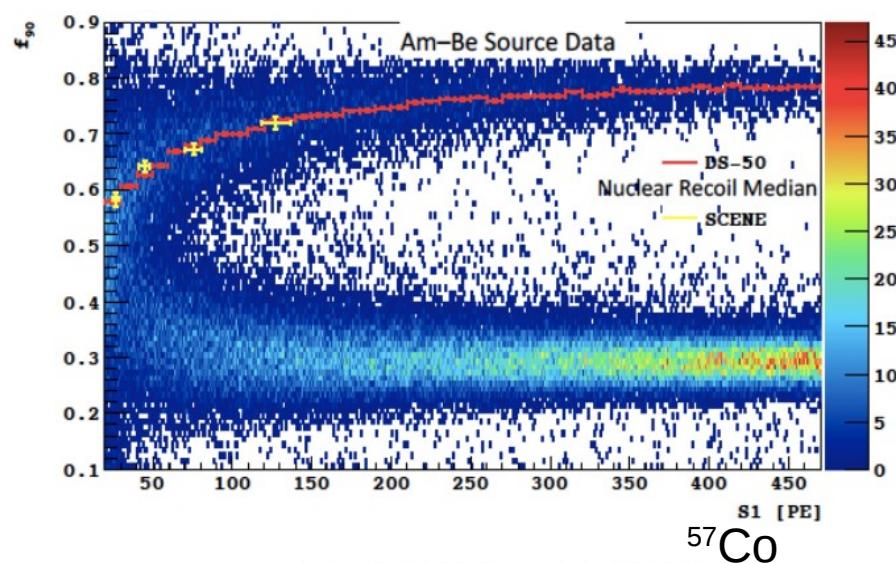
- Discrimination through S1 pulse shape (**F90**)

- Discrimination through **S2/S1**

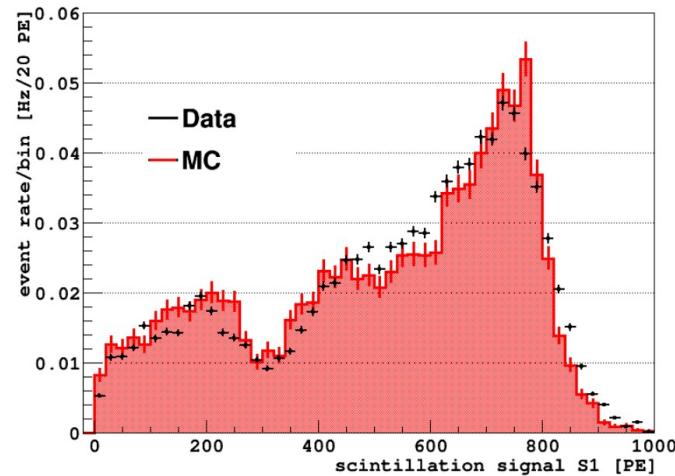
$$F90 = \frac{\int_0^{90\text{ ns}} S1(t) dt}{S1}$$

# Calibrations (TPC and LS Veto)

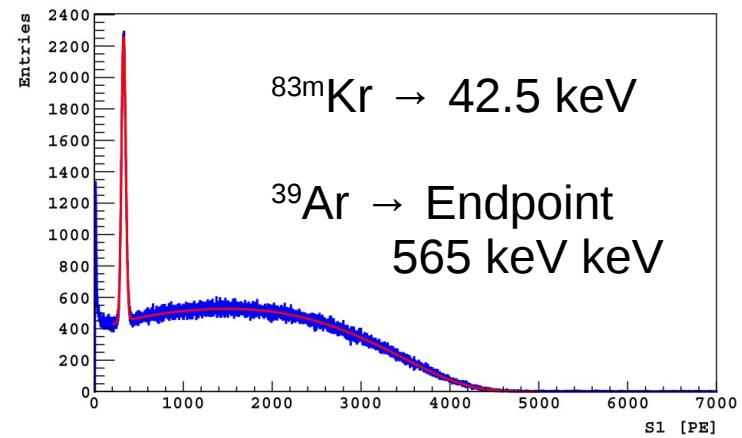
External



AmBe (neutrons)



Internal



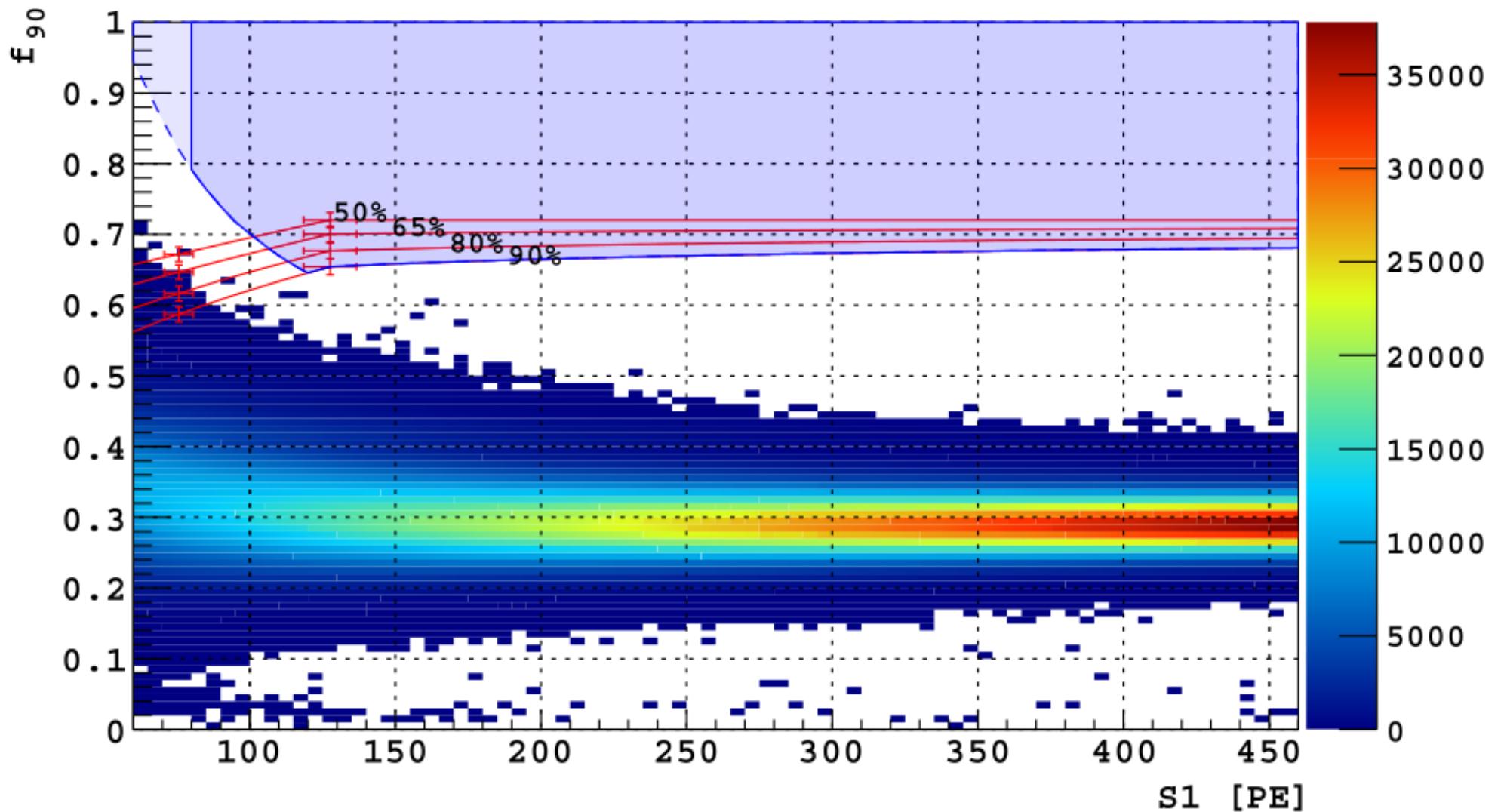
Calibration  
Insertion  
System  
(CALIS)



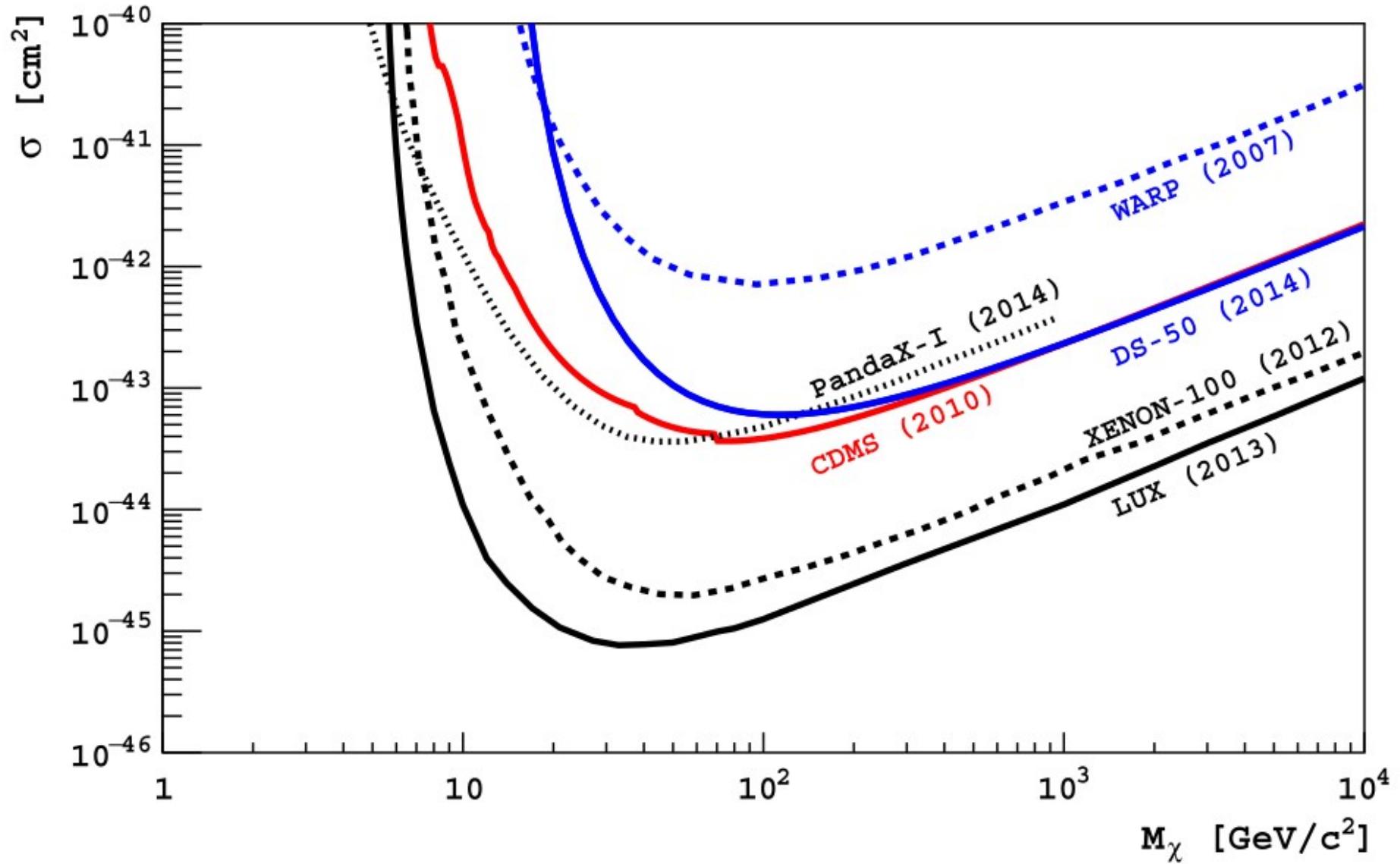
# DarkSide-50 (AAr) first result

Exposure: 1422 Kg day AAr ~ 1 ton year of UAr

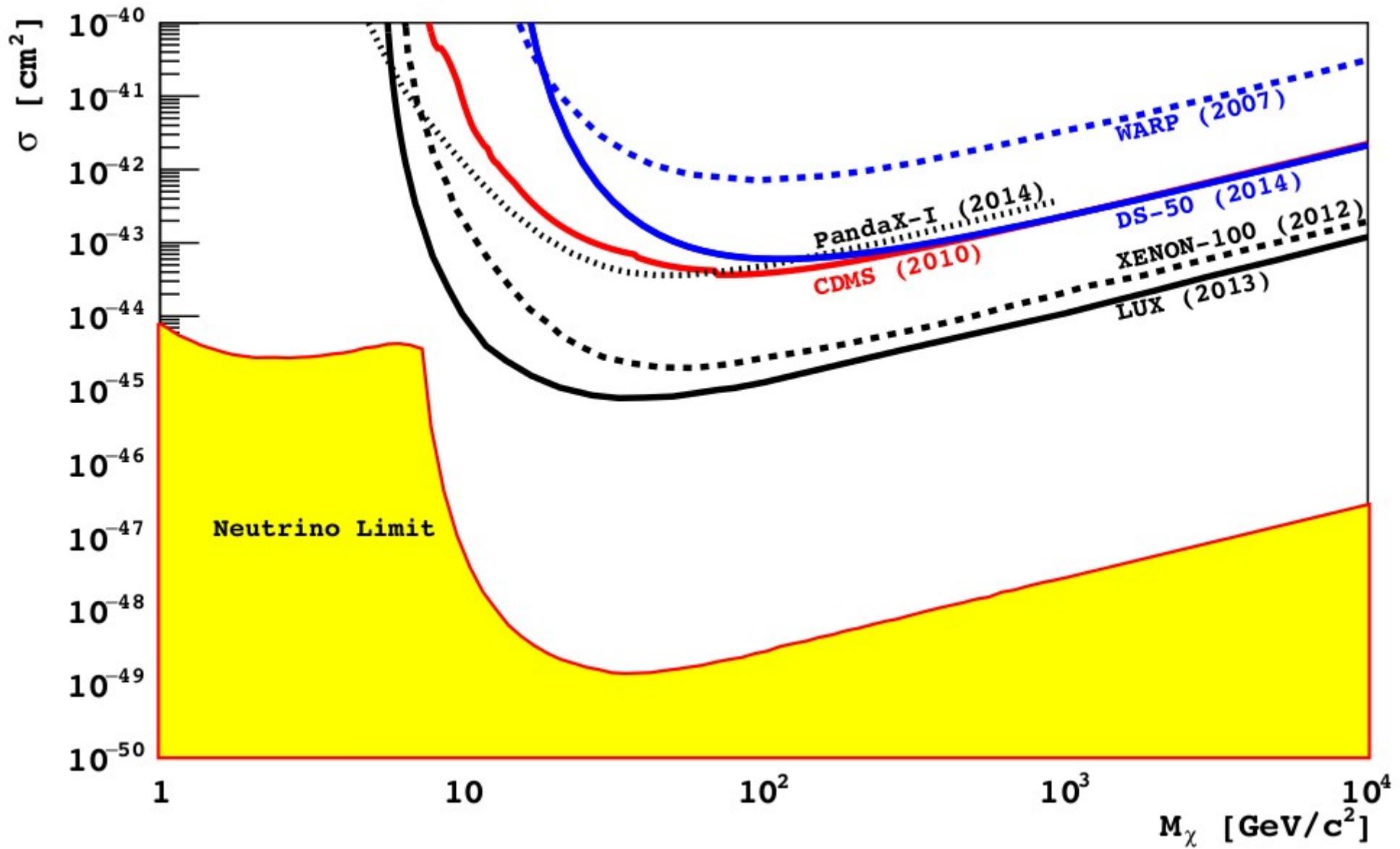
Rejection factor > 1:10<sup>7</sup>



# The best limit with Ar target



# The 3<sup>rd</sup> best limit at large $M_W$



# Underground Argon Campaign



Activity in AAr due to the presence of  $^{39}\text{Ar}$ :  
1 Bq/Kg (cosmogenic activation)

UAr activity measured less than a factor  
300 with respect to AAr

→ **good for multi-ton scaling**

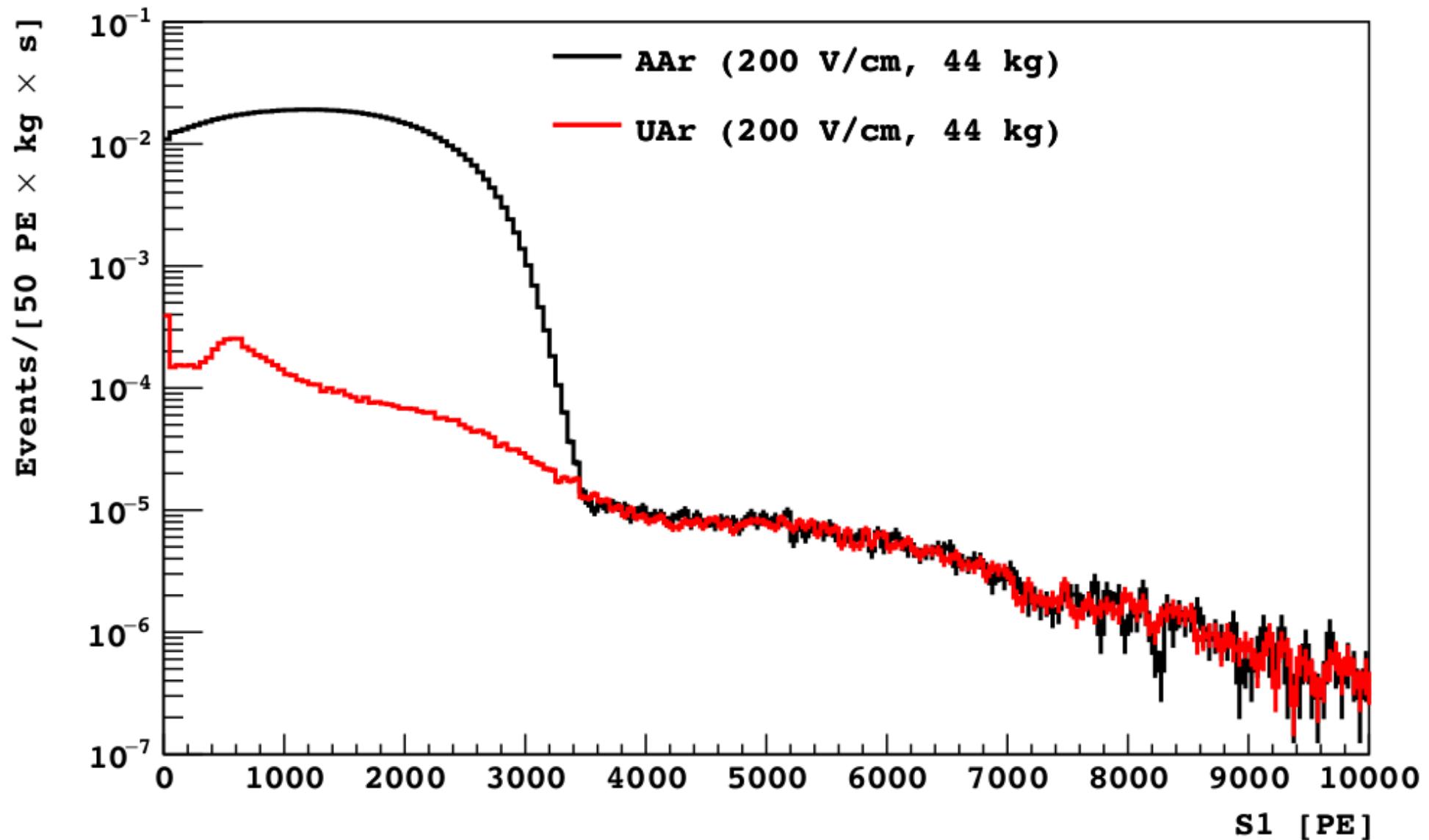
## Underground Argon production:

- Extracted in New Mexico
- Distilled in FermiLab
- Shipped to LNGS

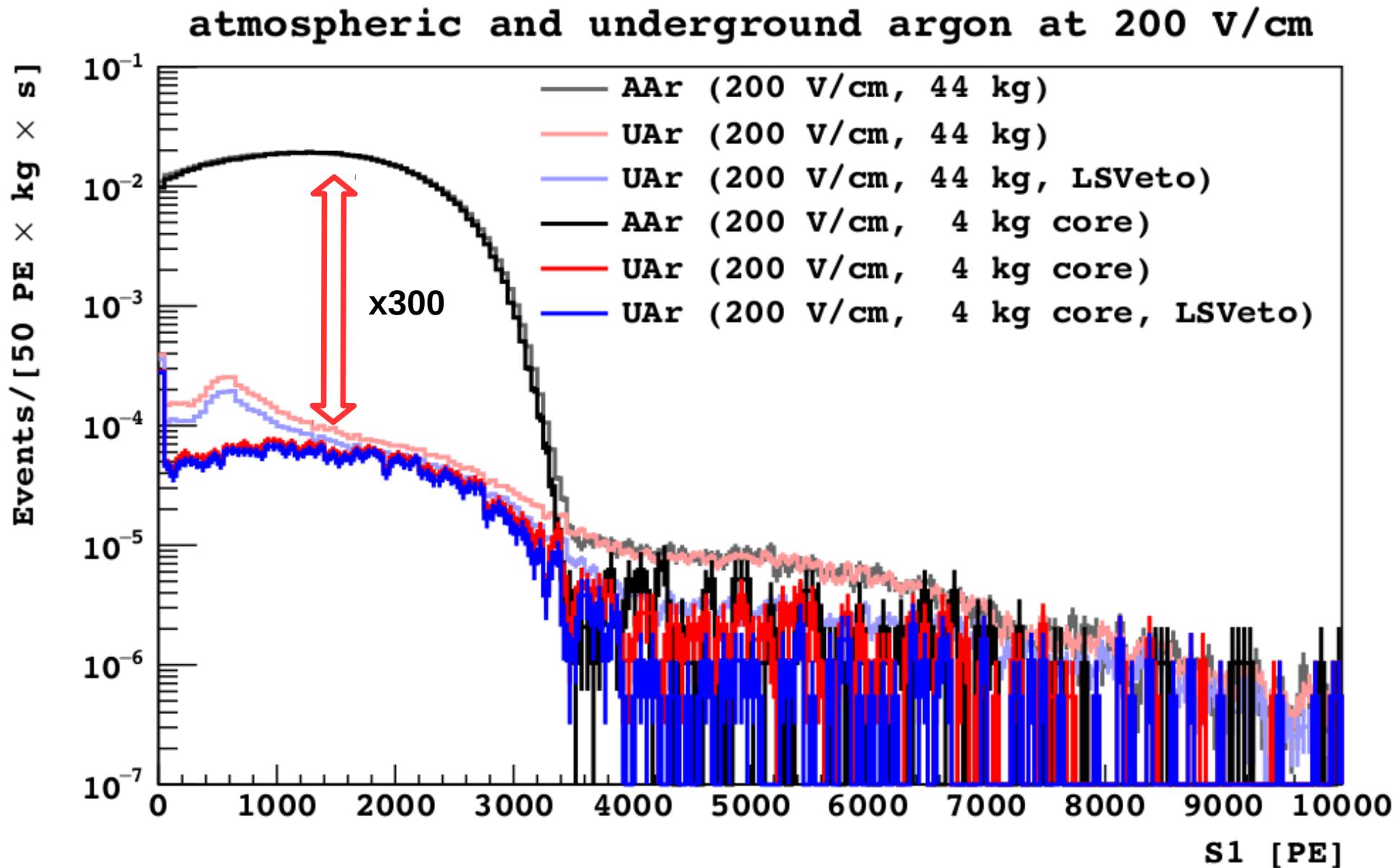
## UAr data taking

- April 2015
- 1.4 ton day already achieved
- Low  $^{14}\text{C}$  TMB replacement in the LS Veto
- New calibrations
- road to  $\sigma \sim 10^{-45} \text{ cm}^2$  sensitivity @ (1TeV)

# First UAr background result



# Inner core and LSV veto



# LAr future plans

**DarkSide-50 Aar**  
1.4 ton day  
 $\sigma \sim 10^{-43} \text{ cm}^2 (@M_w = 1 \text{ TeV})$

**DarkSide-50 UAr**  
~ 1 ton year  
 $\sigma \sim 10^{-46} \text{ cm}^2 (\text{th}) (@M_w = 1 \text{ TeV})$

**DarkSide-20k**  
 $\sigma \sim 9 \times 10^{-48} \text{ cm}^2 (@M_w = 1 \text{ TeV})$   
**Intermediate stage**

**Future:**  
**Argo (300 ton)**  
**(The ultimate experiment**  
**in Dark matter search**

~ 1000 ton year  
 $\sigma \sim 9 \times 10^{-49} \text{ cm}^2 (@M_w = 1 \text{ TeV})$

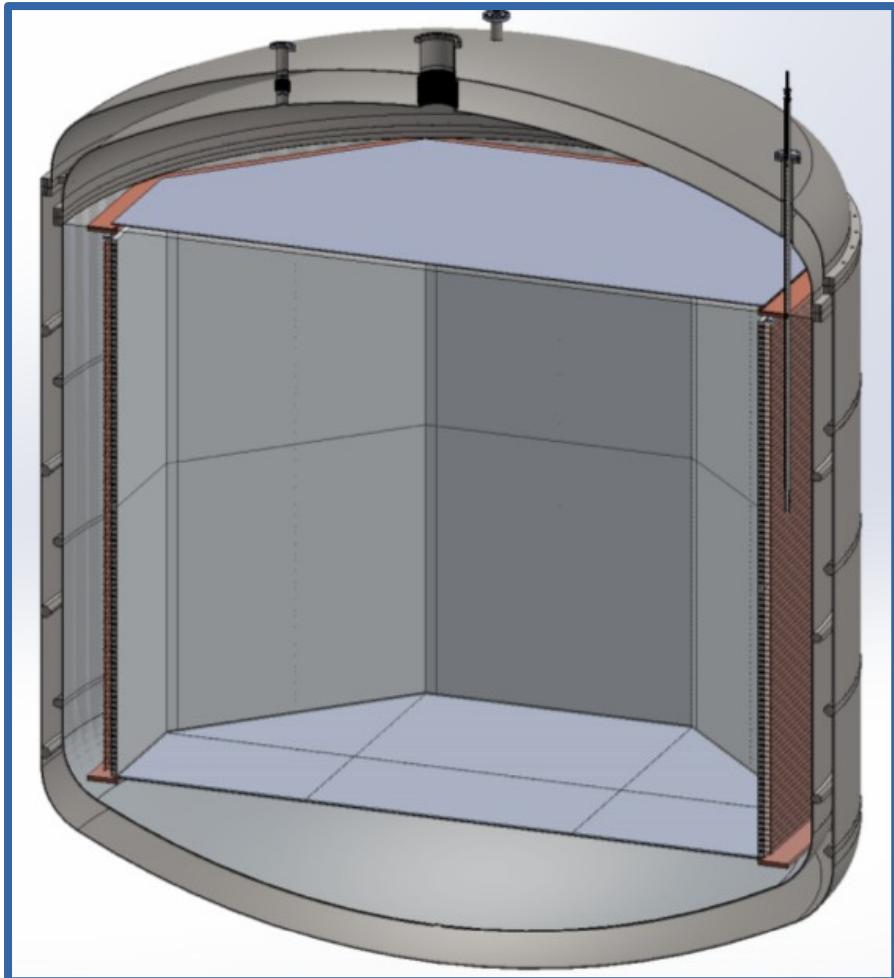
# DarkSide-20k LOI (2015)

D. Franco, A Tonazzo - APC Paris  
D. Alton - Augustana College  
A. Kubankin - Belgorod National Research University  
K. Keeter, B. Mount - Black Hills State University  
L. Romero, R. Santorelli - CIEMAT  
S. Horikawa, K. Nikolic, C. Regenfus,  
A. Rubbia - ETH Zürich  
S. Pordes - Fermilab  
A. Gola, C. Piemonte - FBK & TIFPA  
S. Davini - GSSI  
E. Hungerford, A. Renshaw - University of Houston  
M. Guan, J. Liu, Y. Ma, C. Yang, W. Zhong - IHEP Beijing  
N. Canci, F. Gabriele, G. Bonfini, A. Razeto, N. Rossi,  
F. Villante - LNGS  
C. Jollet, A. Meregaglia - IPHC Strasbourg  
M. Misziazek, M. Woicik, G. Zuzel - Jagiellonian University  
K. Fomenko, A. Sotnikov, O. Smirnov - JINR  
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A. Derbin, V. Muratova, D. Semenov,  
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B. Rossi - Università Federico II & INFN Napoli  
C. Dionisi, S. Giagu, M. Rescigno - Università La Sapienza & INFN Roma  
S. Bussino, S. Mari - Università & INFN Roma 3  
J. Maricic, R. Milincic, B. Reinhold - University of Hawaii  
P. Cavalcante - Virginia Tech

# DarkSide-20k

## Main Features



- SiPM (FBK): LY increased 15-50% (preliminary tests look promising)
- 30 ton LAr (20 ton Fiducial Volume)
- No LSVeto
- Titanium from Russia (low radioactivity)

### **“Urania” project:**

- expansion of Colorado UAr extraction facility to reach 100 kg/day

### **“Aria” project:**

- Big cryogenic distillation column in Seruci, Sardinia (~300 mt high, 1000 stages)
- Gas purification AND active isotopic depletion exploiting finite vapor pressure difference  $^{39}\text{Ar}/^{40}\text{Ar}$  (99% efficiency → ~10  $\mu\text{Bq/Kg}$ )

# Conclusions

- Ar technology shows good performances for Dark Matter search, especially thanks to the high rejection power
- DarkSide-50 AAr & UAr is demonstrating the feasibility of the detection based on LAr
- LAr detectors can be scaled to multi-ton and are the most powerful background-free technique for the ultimate experiment in Dark Matter search (neutrino floor)

# Thank you for your attention!

